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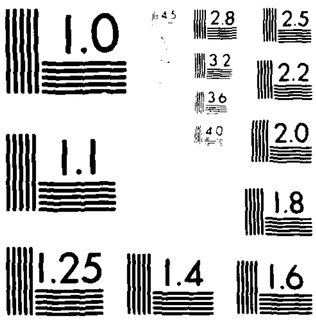

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Materials Technical Memorandum 374

DEVELOPMENT OF A TUBULAR COMPARATOR FOR RADIOGRAPHIC EVALUATION OF STEEL TUBE STRUCTURES

D.A. OLLEY

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SUMMARY

A description is given of the development of a tubular comparator, containing internal blind holes, for application in the radiographic inspection of tubular components suspected of being corroded on their inner surfaces.

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16. ABSTRACT:

A description is given of the development of a tubular comparator, containing internal blind holes, for application in the radiographic inspection of tubular components suspected of being corroded on their inner surfaces.

CONTENTS

1. INTRODUCTION

Radiographic methods used to estimate the extent of corrosion damage to the inside walls of tubular structural components rely very largely on the ability and experience of the individual radiographers. Obviously, it is desirable to reduce the subjective nature of this form of non-destructive inspection. A comparator, described herein, was developed to facilitate more quantitative assessment of internal corrosion damage. Although the method described was developed to aid in the interpretation of radiographs for a specific application, it may have a more general application.

The specific problem which led to this development concerned corrosion in the tubular structure supporting the engine of a military light transport aircraft. The corrosion on the inner surfaces of these tubes usually consists of isolated regions of pitting corrosion. Radiographic inspection was required to assess the extent of reduction in the cross-sectional area of tubes suffering internal corrosion damage.

2. EXPERIMENTAL

2.1 Measurement of Residual Strength

Two steel tubes from the aircraft engine sub-assemblies, which were deemed unserviceable, according to current radiographic evaluation, were tested to failure under tensile loads. The loads at failure exceeded the minimum values specified by the aircraft acceptance limits. Moreover, the overload failures, at the fork ends of the tubular assemblies, bore no relation to any areas of corrosion damage. These destructive tests revealed that, although the corrosion damage observed in the radiographs was adjudged as sufficiently serious for rejection of the engine support frames, it did not significantly affect the strength or location of failure in the overload test. Thus, it is considered that the current radiographic technique overestimates the degree of corrosion damage and its effect upon residual strength of the strut.

2.2 Manufacture of Tubular Comparator

A series of tubular comparators were developed to provide a more accurate means of assessing the effect of internal corrosion damage. The comparators, Fig. 1, were fabricated from sheet material of the same type and gauge as the tubes to be inspected. For the present application seven comparators, ranging in thickness from 20 gauge (0.91 mm) to 9 gauge (3.66 mm) were manufactured.

Before fabricating into tubular form, a series of blind holes of specific depths were drilled into the sheets of various gauges (Appendix A). After fabricating to tube form the holes are aligned along one internal face of the tube. The comparators were coated with the same paint system, but of contrasting colours, as that used on the engine support frames, and a trailing flag attached; the contrasting colours of the tubular comparator and flag reduce the risk of the comparator being left in the engine support assembly, (Fig. 2).

2.3 Radiographic Technique

In use, the appropriate comparator is attached to the engine support sub-frame tube to be radiographed, aligned so that the array of internal holes is nearest the X-ray film, i.e. remote from the radiation source. The side of the comparator containing the array of blind holes is identified by a 5 mm wide red line painted along the length of the tube, (Fig. 1). The conical X-ray beam is directed symmetrically about a point centred on the interface between the comparator and the engine support tube, (Fig. 2).

2.4 Practical Recommendations

The following film dimensions are recommended:

(i) Length of film; 350 mm maximum (limited by the diameter of the emergent X-ray beam); two or more exposures may be required for inspection of the longest engine support tubes.

(ii) Width of the film; sufficient to cover both the tube being inspected and the adjacent comparator.

(iii) The grain size of the film used for this application should be equal to, or finer than, Kodak Industrex type M. The film density, developed on the radiographic image of the comparator in the zone containing the cluster of internal holes, has to be within the optical range 1.5 to 2.0.

2.5 Analysis of Radiographs

Exposed radiographs are processed and viewed in the conventional manner. Where no signs of damage and internal corrosion in the engine support strut is apparent, the normal acceptance criteria applies. For other radiographs, showing varying degrees of internal surface corrosion damage, the radiographic images of the comparator and tube frame are inspected using a micro-densitometer to record a

series of scan traces. Traces are taken along three reference paths (Fig. 3a,b,c) and, at least, three scan paths (Fig. $3a_1,b_1.c_1$) on the radiograph. The density traces, calibrated against density changes for known hole depths in the comparator tube, show directly the depth of corrosion pits, and/or reduction in wall thickness resulting from corrosion. When both general thinning of the tube wall and pitting occur, the trace exhibits 'peaks' above the base density level, corresponding to the pit sites. Thus, the pen trace indicates the profiles of pits which may act as stress raisers (Fig. 4).

The estimates of reduced wall thickness and pit depth are reasonably consistent with values obtained by direct measurement of metallographic sections; examples of some measurements are given in Table 1.

TABLE 1

	Radiographic Comparator Estimates	Metallographic Measurement
Major Pits	0.245 mm 0.305 mm	0.203 mm 0.25 mm
Max Wall Thickness Reduction	17 per cent	16.2 per cent

2.6 Direct Quantitative Analysis

As outlined above, the tubular comparator provides an improved technique for the assessment of internal damage to tubular structures. Work is now in hand to analyse radiographs of comparator and tubes by direct read-out from the densitometer scans. By digitizing the image profiles, maximum pit depths can be identified and computer integration can give the total material loss through corrosion and identify the areas of cross-sectional reduction most likely to affect residual strength.

3. CONCLUSION

An improved radiographic technique for assessing internal damage in tubular steel structures has been developed. The method is based upon the use of tubular comparators containing blind holes, of various depths, which provide representative step reductions in cross-section and thus facilitate estimation of the seriousness of corrosion pits.

The radiographic technique has been successfully applied to an evaluation of corrosion damage in a steel tube which forms part of an aircraft engine support structure.

APPENDIX A

Manufacture of Tubular Comparators for X-Radiography of Aircraft Engine Support Structure

1. MATERIAL REQUIRED

To cover the range of tube dimensions in the aircraft engine support structure, seven comparator tubes were required. The comparators were fabricated from mild steel sheet of the following dimensions.

(1) 150 mm X 115 mm X 0.91 mm (20 Gauge)

(2) 150 mm X 115 mm X 1.22 mm (18 Gauge)

(3) 150 mm X 115 mm X 1.42 mm (17 Gauge)

(4) 150 mm X 115 mm X 2.03 mm (14 Gauge)

(5) 150 mm X 115 mm X 2.64 mm (12 Gauge)

(6) 150 mm X 115 mm X 3.25 mm (10 Gauge)

(7) 150 mm X 115 mm X 3.65 mm (9 Gauge)

The sheets must be flat to within 0.2 mm.

2. DIMENSIONS OF HOLES

The holes were machined into the sheets at the positions shown in the attached drawing (Fig. A1). During the machining operation, the sheet had to be kept as flat as possible to ensure accurate tool tip depth. Machining was carried out using a 2.38 mm (3/32 inch) end mill; the bottoms of the holes had to be flat. The depth of the holes is given in Table A1. Care must be exercised, when marking out the sheets, to avoid score marks which could introduce unwanted artifacts and thus affect micro-densitometer readings.

3. FABRICATION

Following machining of the blind holes of specified depth, the sheet was rolled into tube form with the holes on the inside wall. The tube was then welded along the open edge. The letter A was stamped on the outside of the tube in the position shown in Fig. A1, at the end of the tube containing the shallowest holes; the tube number was stamped on the other end of the tube, opposite the holes. A metal flag 115 X 115 mm X 1.5 mm was attached to the comparator by a 150 mm cable.

4. FINISHING

The comparator, after fabrication, was finished with a chromate-conversion undercoat and a polyurethane top-coat, in the colours shown in Fig. 1 of the memorandum. A thin covering of undercoat was also applied to the inside walls of the comparator tube. Care was taken to avoid paint runs.

TABLE A1. HOLE DIMENSIONS IN COMPARATOR BLANKS

COMPARATOR NUMBER	HOLE ARRAY NUMBER	DEPTH IN mm ±0.002	DEPTH IN INCHES
1	A	0.127	0.005
	B	0.190	0.0075
(20 Gauge)	C	0.254	0.010
	D	0.380	0.015
	E	0.508	0.020
2	A	0.127	0.005
(18 Gauge)	B	0.254	0.010
&	C	0.380	0.015
3	D	0.508	0.020
(17 Gauge)	E	0.635	0.025
4	A	0.127	0.005
(14 Gauge)	B	0.254	0.010
5	C	0.508	0.020
(12 Gauge)	D	0.762	0.030
	E	1.016	0.040
6	A	0.127	0.005
	B	0.254	0.010
(10 Gauge)	C	0.508	0.020
	D	1.016	0.040
	E	1.524	0.060
7	A	0.127	0.005
	B	0.254	0.010
(9 Gauge)	C	0.508	0.020
	D	1.016	0.040
	E	2.032	0.080

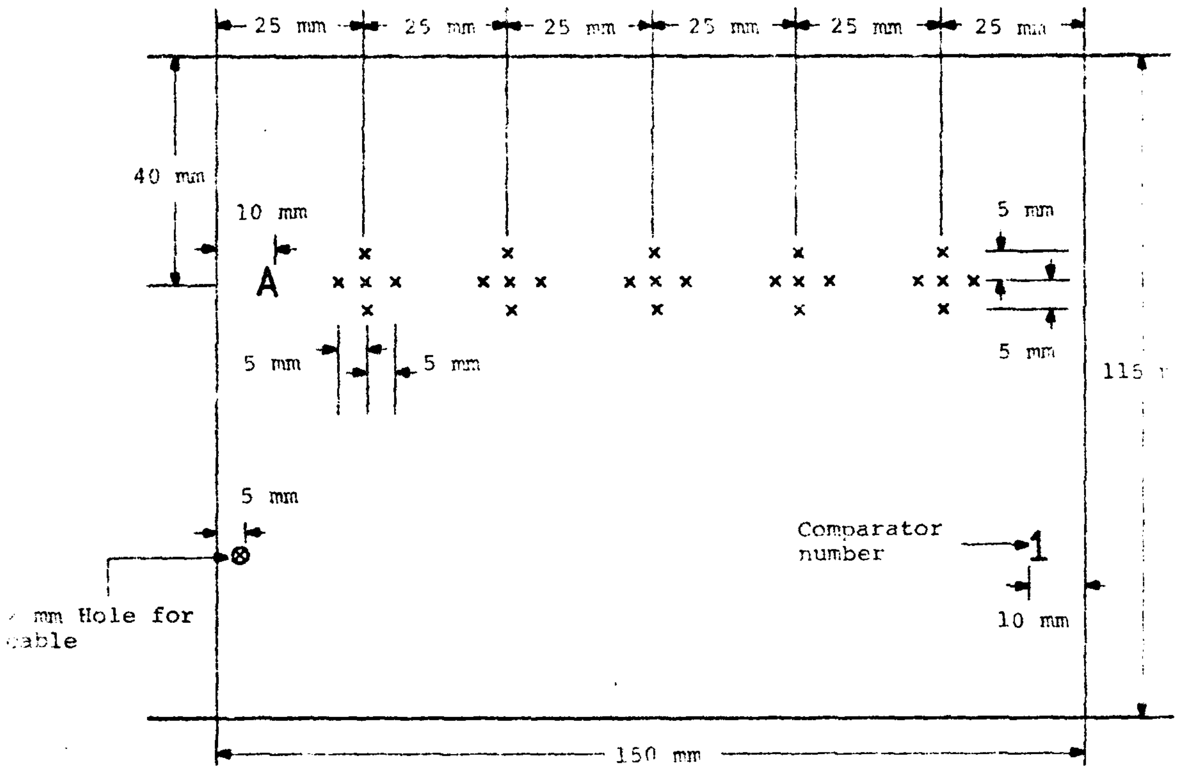

FIG. A1. A plan view of the comparator showing locations of the hole arrays.

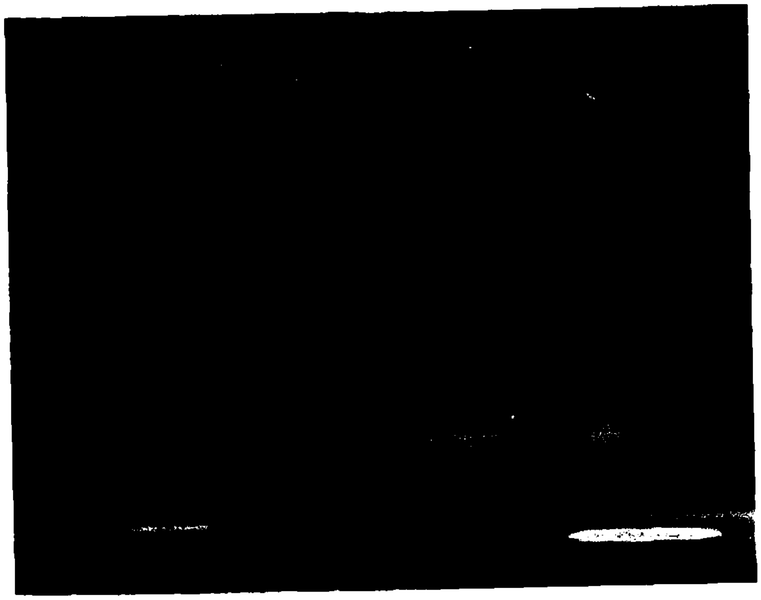

FIG. 1. The conspicuously coloured tubular comparator adjacent to part of a tubular engine-support structure. The 5 mm wide red stripe identifies the position of the array of blind holes along the immediate inside wall of the tube.

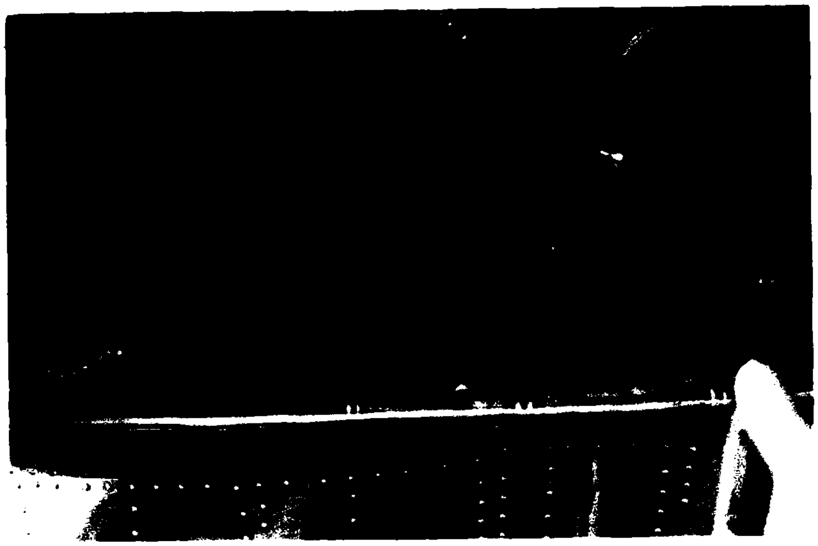

FIG. 2. Showing the ease of identification of the contrasting colours of the comparator in an HS748 engine assembly. The aiming position of the X-ray beam is symmetrical about the interface between comparator and engine mount tubes.

FIG. 3. Shows radiographic images of comparator and corroded tube. Micro-densitometer reference scans are taken parallel to the tube axis at positions a, b and c for the comparator and a_1, b_1, and c_1 for the internally corroded tube.

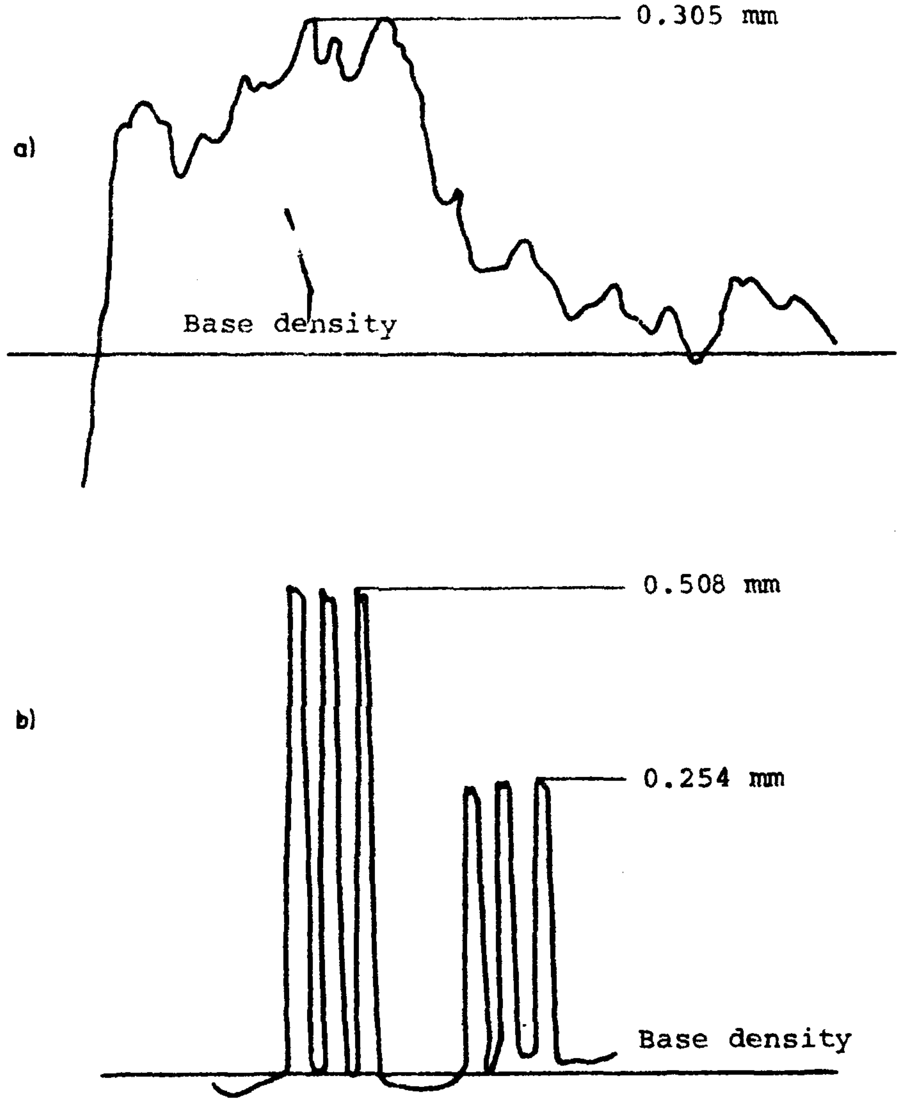

FIG. 4. Scanning Micro-densitometer traces of the radiograph showing:

(a) Corrosion damage in the tube (Trace a_1, Fig. 3).

(b) The reference comparator holes.

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